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Study of Stiffened Central Panel Between Two Openings in Steel Plate Shear Walls with Stiffeners

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ABSTRACT

The performance of the central panel in dual-opening steel shear walls has been studied using the simple beam model, which its behavior depends on the "height to width" ratio. Central panel has been made of bilateral stiffeners on both sides of the web plate. Now, the central panel together with extreme stiffeners is comparable to a steel shear wall by itself. It is necessary for the cross-sectional area of the stiffeners to meet the minimum requirements to force the ideal shear yielding of the central panel rather than the flexural yielding of side stiffeners. Obviously, the "height to width" ratio of the central panel has been studied as a major factor in predicting its behavior. ABAQUS is the analytical tool used in the paper. It has also been concluded that the proper ratio selected for the central panel would result it to behave in a dominant shear mode.

KEYWORDS

Steel Plate Shear Walls, Stiffener, Rectangular Openings, Stiffened Central Panel.

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1- INTRODUCTION

Steel plate shear wall (SPSW) Systems have been extensively investigated, both theoretically and experimentally by researchers such as Astaneh-Asl, Driver, Kulak, Thorburn, Bruneau, Berman and Park. One of the premier experimental studies on the scaled models of SPSWs were conducted at the structural laboratory of Cardiff University in UK. In this series of experimental studies, scaled models of unstiffened steel plate shear walls with a central circular opening were subjected to pseudo-static cyclic loading. Obtained results showed stable S-shaped hysteretic response with a considerable energy absorption capacity that would increase with increased shear deformation of the panel. It was demonstrated that increasing the diameter of the opening would result in the degradation of stiffness and strength of the panel relative to similar panel without opening.

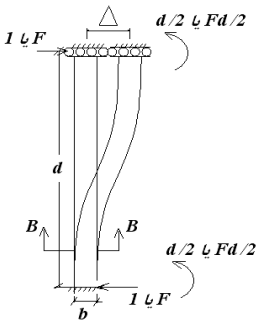
In 2004, some specimens of steel plate shear walls were tested in National Taiwan University. One of them had twenty circular openings and the other one, had a quarter circle shaped opening in one corner. In specimens with opening(s), reduction of stress and stiffness was observed compared to those of the similar walls without opening.

Choi and Park in 2007, conducted experimental tests to investigate the changes of structural capacity of SPSWs with different details of the web plates. The results demonstrated that selection of different constructional details of web plates for the architectural and economical considerations will not significantly decrease the structural capacity of steel plate shear wall specimens.

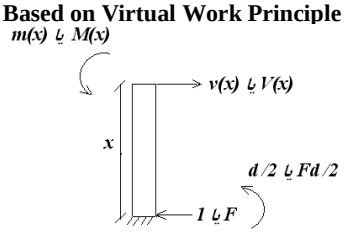
2- METHODOLOGY

The purpose of this paper is to theoretically and numerically investigate the central panel between two openings in steel plate shear walls as a beam and to propose the equations for determining limits for "height to width ratio" to predict the central panel's response. The effect of variation of the central panel's aspect ratio on its behavior is investigated in this study. Other equations are also set up for calculating the "minimum cross sectional area of the panel's dual side stiffeners". Comparisons between the theoretical and numerical results have been showed that selection of the proper value for the central panel's aspect ratio would result it to behave in a dominant shear mode.

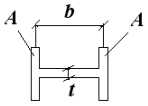
In figure (1), central panel simulated to an I-shaped beam is shown. Figures (2) and (3) show the finite element models "SSWOS-1" and "SSWOS-13" with the height to width ratio of 0.7 and 9, respectively.



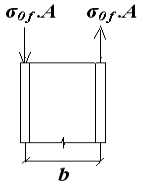
(a) Modeling of Central Panel as a Beam under Loading Based on Virtual Work Principle



(b) Free Body Diagram of Central Panel in a Section at Distance, *x*, from the Base Level



(c) Cross-Section of the Beam



(d) Axial Force in the Column Flanges

FIG. 1. CENTRAL PANEL SIMULATED AS AN I-SHAPED BEAM

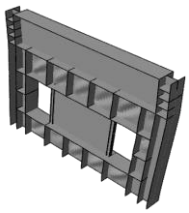


FIG. 2. DEFORMED SHAPE OF SSWOS-1 MODEL WITH d_1/b_1=0.7

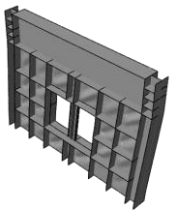


FIG. 3. DEFORMED SHAPE OF SSWOS-13 MODEL WITH d_1/b_1=9

3- FINDINGS

Equations (1) and (2) are the main equations which have been obtained in this research:

$$A \geq \frac{\sigma_{0w} t d}{2\sqrt{3}\sigma_{0f}} \quad (1)$$

$$\frac{d}{b} \leq 2\sqrt{3}(1+\mu)\frac{\sigma_{0w}}{\sigma_{0f}} \quad (2)$$

Where:

A	Cross-sectional area of side stiffeners
σ_{0w}	Yield stress of the plate
σ_{0f}	Yield stress of side stiffeners
t	Thickness of the plate
d	Height of the panel
b	Width of the panel
μ	Poisson's ratio

Figures (4) and (5) indicate Von-Mises stress versus displacement variation curves for SSWOS-1 and SSWOS-13 models, respectively. Figure (6) shows the limiting values of the central panel's aspect ratio (d_1/b_1) that separates the shear and the flexural behavior of it, using yield stress values of 192.4 MPa and 414.9 MPa for the web plate and side stiffeners, respectively.

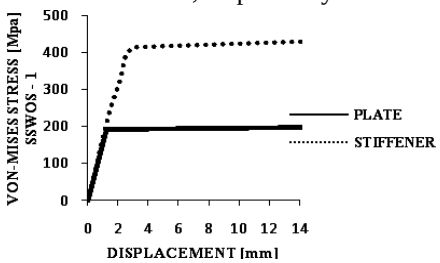


Fig. 4. VON-MISES STRESS VERSUS DISPLACEMENT VARIATION CURVE FOR SSWOS-1 MODEL WITH d_1/b_1=0.7

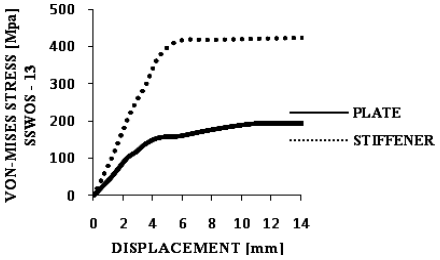


Fig. 5. VON-MISES STRESS VERSUS DISPLACEMENTS VARIATION CURVE FOR SSWOS-13 MODEL WITH d_1/b_1=9

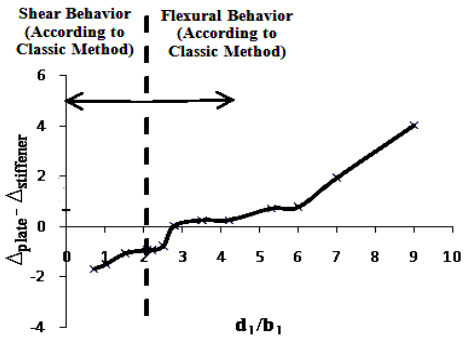


FIG. 6. RELATIVE DISPLACEMENT BETWEEN VALUES OF PLATE AND STIFFENER DISPLACEMENTS AGAINTS ASPECT RATIO (D_1/B_1) AT THE STARTING TIME OF YIELDING

4- RESULTS

The results obtained from this paper can be described as follows:

According to the numerical studies:

1-In a central panel, with the height to width ratio less than 2.8, yielding of the plate commences at first and the response of the panel is predominantly influenced by shear.

2- In a central panel, with the height to width ratio greater than 2.8, yielding, at first, commences in the side stiffeners and the response of the panel is predominantly influenced by flexure.

3- Numerical analyses show that by using steel with yield stress of 192.4 MPa for the web plate and 414.9 MPa for the dual side stiffeners, the height to width ratio of 2.8 is the limiting value. In the stiffened central panels with the height to width ratio greater than this value, the behavior of the panel is dominated by flexure rather than shear and in the panels with aspect ratio less than this value, shear behavior is dominated to the flexural behavior.

On the other hand, theoretical studies show this limiting value to be 2.1. Although two experiments were undertaken to verify the accuracy of these numerical studies, further detailed experimental studies are needed for obtaining comprehensive results, in particular for investigating the role of the panel supporting frame, on the behavior of SPSW.

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